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TITLE: A REFLUX CLASSIFIER

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I, ANNA MAIJA MADL, ACTING TEAM LEADER EXAMINATION SUPPORT & SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PP 8481 for a patent by THE UNIVERSITY OF NEWCASTLE RESEARCH ASSOCIATES LIMITED filed on 02 February 1999.

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WITNESS my hand this
Seventh day of March 2000

A. M. Madl

ANNA MAIJA MADL
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PRIORITY DOCUMENT

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AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

Applicant(s):

THE UNIVERSITY OF NEWCASTLE RESEARCH ASSOCIATES LIMITED

A.C.N. 000 710 074

Invention Title:

A REFLUX CLASSIFIER

The invention is described in the following statement:

A REFLUX CLASSIFIER

The present invention relates generally to a method or an apparatus for segregating or classifying particles. The invention relates particularly, though not exclusively, to a fluidized multistage lamellae classifier or reflux classifier, being designed for segregating particles according to size and possibly density.

In many industrial processes it is necessary to classify particles according to their size, and sometimes according to their density. For example, in mineral processing screens, cyclones, and elutriators are often used to sort particles prior to downstream beneficiation. Classification may proceed either in a wet or a dry state. Although the aim may be to separate the particles at a specific size, there is usually a high degree of so-called misplaced material, with a portion of coarse particles reporting with the fine particle stream, and fine particles reporting with the coarse particle stream. An "S" shape partition curve provides a measure of the probability of a given particle size reporting to a given stream, and hence the efficiency of the separation.

In principle, sieves should provide the perfect separation, given that a particle will only pass through the sieve if it is smaller than the openings. However, if the particles are not given sufficient time on the sieve a poor separation will be achieved. Relatively fine particles, less than 45 µm in diameter, readily adhere to other particles, and are therefore difficult to separate using sieves. Sieves also tend to become blinded by particles which are similar in size to the openings, and operate poorly when particles are fed on a continuous basis.

Elutriators separate particles according to their settling velocity. If the particles are of the same density, then

the separation proceeds in accordance with the particle size. A liquid passes up through the vessel at a specific velocity, carrying slower settling particles to the top, thus allowing faster moving particles to be withdrawn from near the base of the vessel. However, elutriators fail to provide satisfactory throughputs, especially when the separation size is relatively small. On the other hand cyclones provide remarkably high throughputs although their efficiency is arguably poorer, and the separation size more difficult to control.

Inclined classifiers have the potential to offer satisfactory throughputs, and efficient separations. Earlier this century Boycott (1920) found that the effective rate of sedimentation could be increased significantly by inclining a vessel. Lamellae thickeners, which are gravity settlers containing parallel plates, are now used in solid-liquid separation. However with these known systems there is no attempt to classify particles, only to remove all particles from much of the liquid. Basically the solids settle onto the plates once only and move downwards as a concentrate. In laboratories, inclined devices have also been used to classify particles according to both size and density (Davis and Gecol, 1996; Thompson and Galvin, 1997; Nelson *et al*, 1997).

According to one aspect of the present invention there is provided a method of segregating particles, said method comprising the steps of:

providing a classifier including a fluidization chamber and one or more inclined plates mounted within said chamber;

locating the particles within the fluidization chamber; and

passing a fluidization fluid through the classifier whereby said fluid elutriates the particles whilst said one or more inclined plates is effective in

increasing particle segregation within the classifier.

According to another aspect of the present invention there is provided a method of classifying particles comprising the steps of:

providing a classifier including a classifier housing and a plurality of adjacent classification stages each having one or more inclined plates mounted within said housing, the classifier being adapted to receive the particles whereby the particles are segregated through each of the classification stages with the inclined plates providing increased particle segregation.

According to a further aspect of the present invention there is provided a classifier for segregating particles, said classifier comprising:

a fluidization chamber being adapted to receive a flow of a fluidization fluid; and

one or more inclined plates mounted within the fluidization chamber whereby in operation the fluidization fluid elutriates particles located within the fluidization chamber whilst said one or more inclined plates is effective in increasing particle segregation within the classifier.

According to yet another aspect of the present invention there is provided a classifier comprising:

a classifier housing; and

a plurality of adjacent classification stages each having one or more inclined plates mounted within said housing, the classifier being adapted to receive particles whereby the particles are segregated through each of the classification stages with the inclined plates providing increased particle segregation.

It is understood that increased particle segregation is largely produced through the use of the inclined plates and

efficient classification achieved by the reflux effect of the fluidization fluid whereby said fluid can repeatedly fluidize into the plates particles of a certain size and/or density.

Generally the particles and vast majority of the fluidization fluid are introduced to the fluidization chamber as separate streams. Alternatively the particles are incorporated in the fluidization fluid which may for example be in the form of a slurry.

Preferably said one or more inclined plates include a lamella of plates disposed adjacent to each other with spaces between the plates for the fluidization fluid to flow. In one example the plates of each lamella are arranged parallel to each other.

Typically there are provided a plurality of stages of lamella of plates within the housing or fluidization chamber. In one embodiment the plates of adjacent lamellae stages are, in the direction of flow of the fluidization fluid, oriented differently whereby progressively slower settling particles pass each adjacent stage. For example, the plates may be longer, closer together and/or less steep in order to achieve this effect. In another embodiment the configuration of plates of adjacent stages is substantially the same. It should be appreciated that other permutations of lamella plate sequences and arrangements are within the scope of the present invention. Generally, the number of lamellae stages assist in dictating the extent to which the particles are eventually segregated.

Typically, there is provided an uppermost lamellae designed to prevent particles from escaping the fluidization chamber together with much of the fluidization fluid. Thus, relatively fine particles can be removed or classified in a more concentrated form from beneath the uppermost lamellae.

Preferably the fluidization chamber or classifier housing is elongate and shaped generally square or cylindrical with the stages of lamellae plates spaced longitudinally along its length. More preferably the fluidization chamber or classifier housing is oriented upright with the fluidization fluid flowing generally upward. Generally the plates are inclined. Additionally the fluidization chamber may be inclined.

Advantageously the step of passing the fluidization fluid through the classifier can involve fluidization at relatively low velocities whereby segregation of the particles occurs largely on the basis of density.

Typically the method or apparatus for segregating or classifying particles is performed as a batch operation. Alternatively the method or apparatus is operated in a continuous mode whereby the particles are continuously or intermittently added to the fluidization chamber or the classifier housing.

Generally the fluidization fluid is water or another liquid. Alternatively the fluidization fluid is a gas. Typically the particles are provided dry or wet as a slurry.

Particles is to be understood to include solids, liquid droplets, and air or other gas bubbles.

In order to achieve a better understanding of the nature of the present invention several preferred embodiments of an apparatus for and a method of segregating or classifying particles will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of a known single layer inclined classifier;

Figure 2 is a schematic representation of one embodiment of a particle classifier according to the present invention operating in a batch mode; and

Figure 3 is a schematic representation of another embodiment of a particle classifier according to the present invention operating in a continuous mode.

By way of background theory a simple kinematic description of solids or particle classification in an inclined device will now be described. A schematic representation of a single plate inclined classifier is shown in Figure 1. Feed solids or particles may enter near the base, producing fine solids or particles in the overflow, and coarse solids or particles in the underflow. The trajectory of a critical size particle which reports both to the underflow and the overflow is shown. The solid particle gradually settles towards the incline as it is carried upwards. Finer solids or particles will report to the overflow, and coarser solids or particles will slide down the incline to the underflow.

The fluid moves through the device at a velocity U, and hence arrives in a time, $t=L/U$, where L is the plate length. During this time the solid particle moves at a velocity $V\cos\theta$ normal to the incline, where V is the particle velocity, and θ is the angle with the horizontal. Assuming a width, W, between the plates, then

$$V\cos\theta = W/t=WU/L \qquad (1)$$

Therefore, the critical particle velocity is,

$$V=WU/(L\cos\theta) \qquad (2)$$

The value of V, at a given suspension concentration depends on the particle size, assuming the solid particle density is constant. Equation 2 provides a basis for selecting the

lamellae width, length and angle. Ideally, the angle should be about 70 to 80 degrees. Higher angles will not amplify the segregation significantly. Lower angles may lead to a build up of solids or particles on the incline.

The sedimentation enhancement is given by the ratio of U/V. That is,

$$U/V = L\cos\theta/W \qquad (3)$$

and hence the increase in settling rate is given by the ratio of the projected settling area to the cross-sectional flow area. By inclining a vessel with a long length L and narrow width W significant rates of separation can be obtained. A lamellae consisting of many plates separated by a narrow gap W has the potential to increase throughputs many fold.

A schematic representation of one embodiment of a particle classifier 10 operated in a batch mode is shown in Figure 2. When the bed is fluidized, solids or particles move upwards into plate lamellae 12A, 12B or 12C, and settle out on to the respective inclined plates 14A, 14B or 14C. The plate lamellae 12A, 12B or 12C are mounted within a fluidization chamber 16 which in this example is elongate and of a generally square or circular cross-section. The finest grade of particle, however, passes up through. Some of the fine particles may deposit onto the inclined plates 14A, 14B, or 14C and hence slide back down into a fluidized region below the lamellae 12A, 12B or 12C. In time, these particles will again move up into the lamellae 12A, 12B or 12C and hence be given a second, third or subsequent chance to escape into the region above the lamellae 12A, 12B or 12C and hence the classifier operates as a reflux classifier. The fluidization process, therefore, helps to strip the suspension of the fine particles. The inclusion of the plate lamellae 12A, 12B or 12C into the fluidization

chamber such as 16 to enhance segregation is an important feature of the invention. A common fluid velocity up through each lamellae is produced automatically because of the steady flow of the fluidization fluid, in this example water.

Once the particles move beyond the first stage of the plate lamellae 12A they then pass through a second lamellae 12B. This lamellae 12B consists, ideally, of longer plates 14B. The plates may also be oriented closer together or inclined with less of a gradient. Therefore, only the finest of the fine particles are capable of passing through the second stage 12B. Again, if these fine particles fail to pass through on the first attempt, additional opportunities will be possible due largely to the reflux effect. Additional lamellae may also be positioned above, such as 12C, with sections in between which are free of lamellae. For example the final or uppermost lamellae, in this case 12C, can be employed to prevent ultrafine particles from escaping the fluidization chamber with the fluidization fluid.

The batch system will eventually produce a steady condition, with the finest particles trapped in the upper sections, and gradually coarser particles trapped in sections closer to the base. The number of lamellae stages such as 12A, 12B and 12C then governs the extent to which the particles are separated. If the plate lamellae 12A, 12B and 12C were not used in the classifier 10, some segregation would occur. However, the applicant has observed that particles covering a broad range of size and density tend to remain mixed in a fluidized bed. Hence, in the absence of the plate lamellae a sharp separation would be impossible.

A schematic representation of another embodiment of a particle classifier 100 operated in a continuous mode is

shown in Figure 3. The particle classifier 100 is readily operated in a continuous fashion by pumping a particle feed slurry into an external feed well 180. An internal feed well may be preferred, but may be more difficult to incorporate because of the plate lamellae. The feed well 180 provides a means for disengaging unwanted entities such as air bubbles from the feed slurry. The feed slurry then ideally plunges into the middle region of the classifier 100. In this embodiment a plate lamellae 120C may be located above the feed entry position and a second stage lamellae 120B may be located below the feed entry position. For further refinement, additional lamellae such as 120A and 120D may be used either side of the feed entry position. A lamellae free section should exist between each set of lamellae 120A, B, C, and D. These sections provide new opportunities for the particles to be classified via the reflux mechanism.

At the top of the fluidizing chamber 160 liquid containing the finer particles spill over into a launder 200 for recovery in a separate vessel (not shown). Alternatively the solids leave in a more concentrated form from the zone between 120C and 120D. The coarser particles suspended near the base are pumped away to another vessel (not depicted). The separation size is governed by the fluidization rate, underflow withdrawal rate together with the plate length, L, angle, θ, and width, W, used in the lamellae.

It has been observed that by operating at a relatively low fluidization velocity, higher suspension concentrations can be produced. Further, if the fluidization liquid contains exceedingly fine dense particles, such as magnetite, higher suspension densities can be produced. These higher densities greatly reduce the settling velocities of the least dense feed particles, and hence the lower density feed particles will tend to report to the overflow.

Therefore, the device can also be used to separate particles on the basis of density.

It will be appreciated that solids or particles which are close to the separation condition have unlimited opportunity to report to the correct position within the classifier such as 10 or 100. This reflux of particles does not represent a significant additional load on the system, as the fraction of the feed particles involved will generally be small. Further, the existence of plate lamellae such as 12 or 120 in the fluidization chamber 16 or 160 permits relatively high throughputs to be achieved because the lamellae 12 or 120 amplifies the differences in particle velocities.

The classifier and method of particle segregation or classification is suitable for feeds containing particles up to about 5 mm in diameter although larger particles could also be used. Ultrafine particles, less than 45 µm in diameter also separate effectively, assuming colloidal aggregation is not a problem. Further it is possible to classify particles into different distinct fractions using batch conditions. For ultrafine particles, this is especially attractive. Hence the classifier and method of classification provide an excellent alternative to a conventional cyclosizer.

Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. For example, according to another aspect of the invention, the classifier may function without a fluidization fluid but rather merely include a classifier housing having a plurality of adjacent classification stages in the form of inclined plates mounted therein. This classifier will operate by gravity sedimentation or centrifugal separation and achieve similar particle refinement to that described

in the preceding paragraph. The classifier including a fluidization chamber may be of practically any configuration where essentially it operates as an elutriator or fluidized bed with the presence of one or more inclined plates and one or more sets of lamellae. The method of segregating or classifying particles may also extend to the following applications:

i) the classification of particles less dense than the fluidization fluid where the described system operates in reverse with the fluidization fluid flowing downwards and the particles settling upwards;

ii) gas fluidization of relatively fine particles;

iii) the segregation or classification of liquid droplets or air bubbles such as that required in the draining of a foam in foam fractionation.

All such variations and modifications are to be considered within the scope of the present invention the nature of which is to be determined from the foregoing description.

Dated this 2nd day of February 1999
THE UNIVERSITY OF NEWCASTLE RESEARCH ASSOCIATES LIMITED
By their Patent Attorneys
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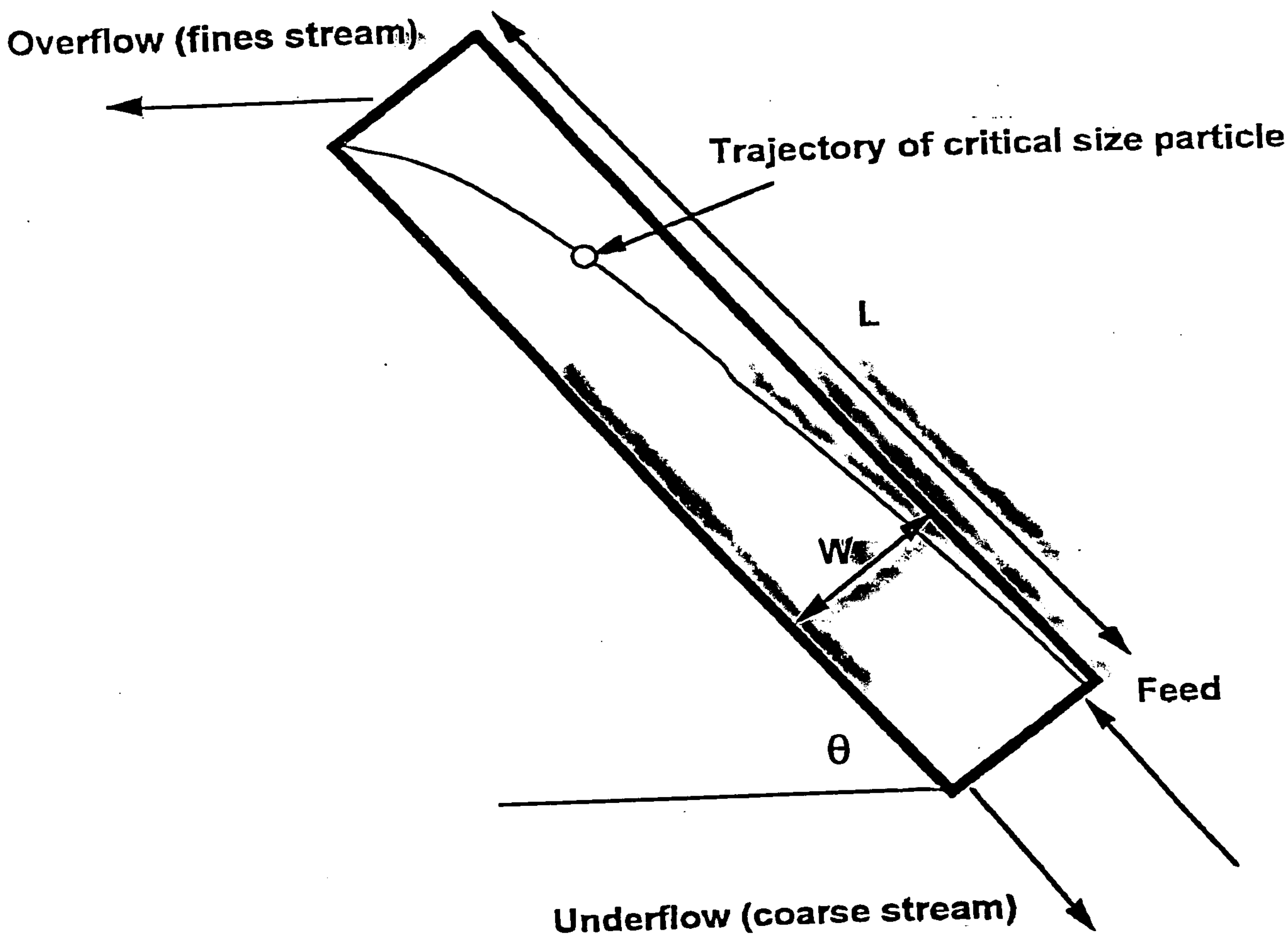

Overflow (fines stream)
Trajectory of critical size particle
L
W
Feed
θ
Underflow (coarse stream)

FIG. 1

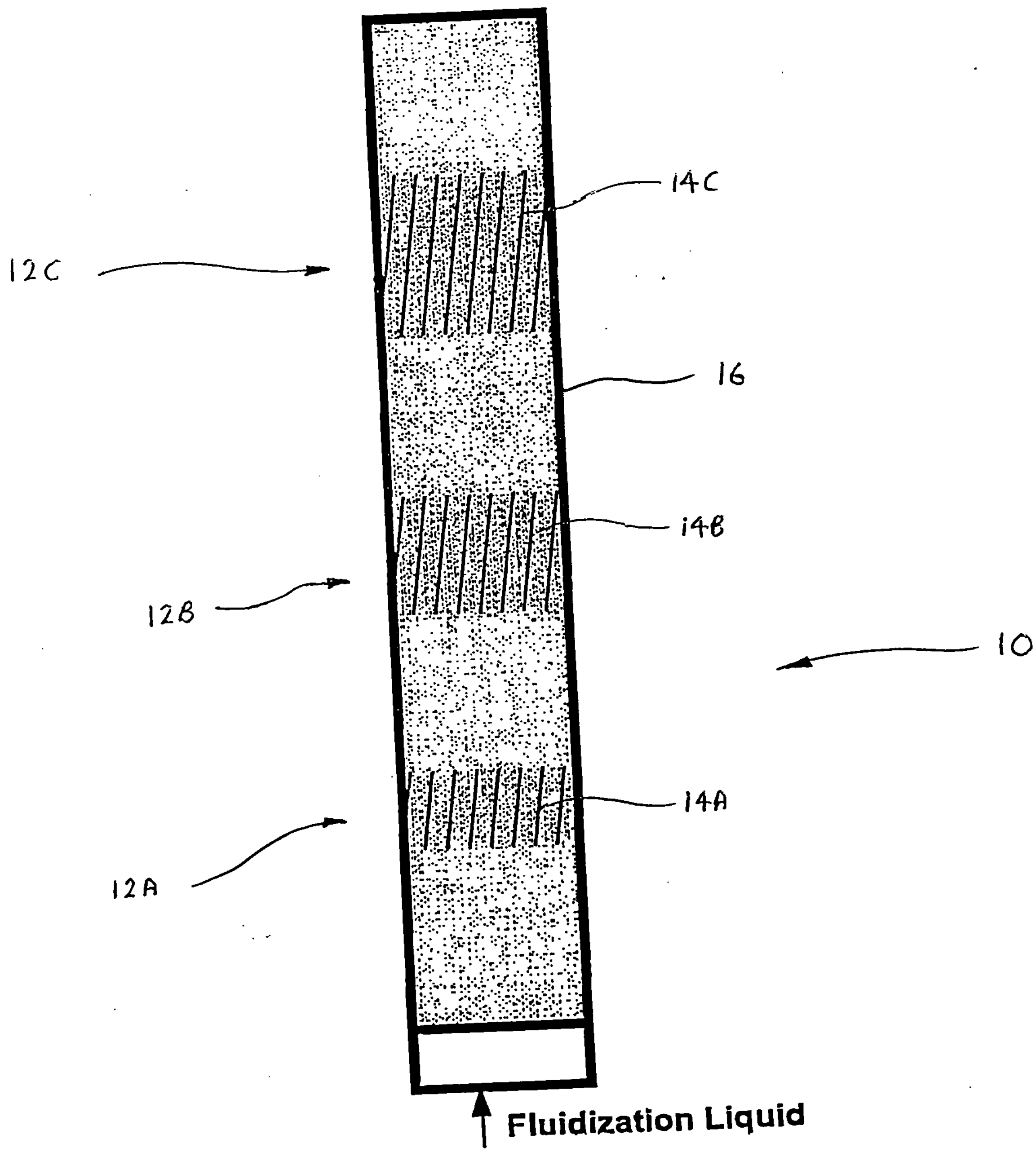

FIG. 2

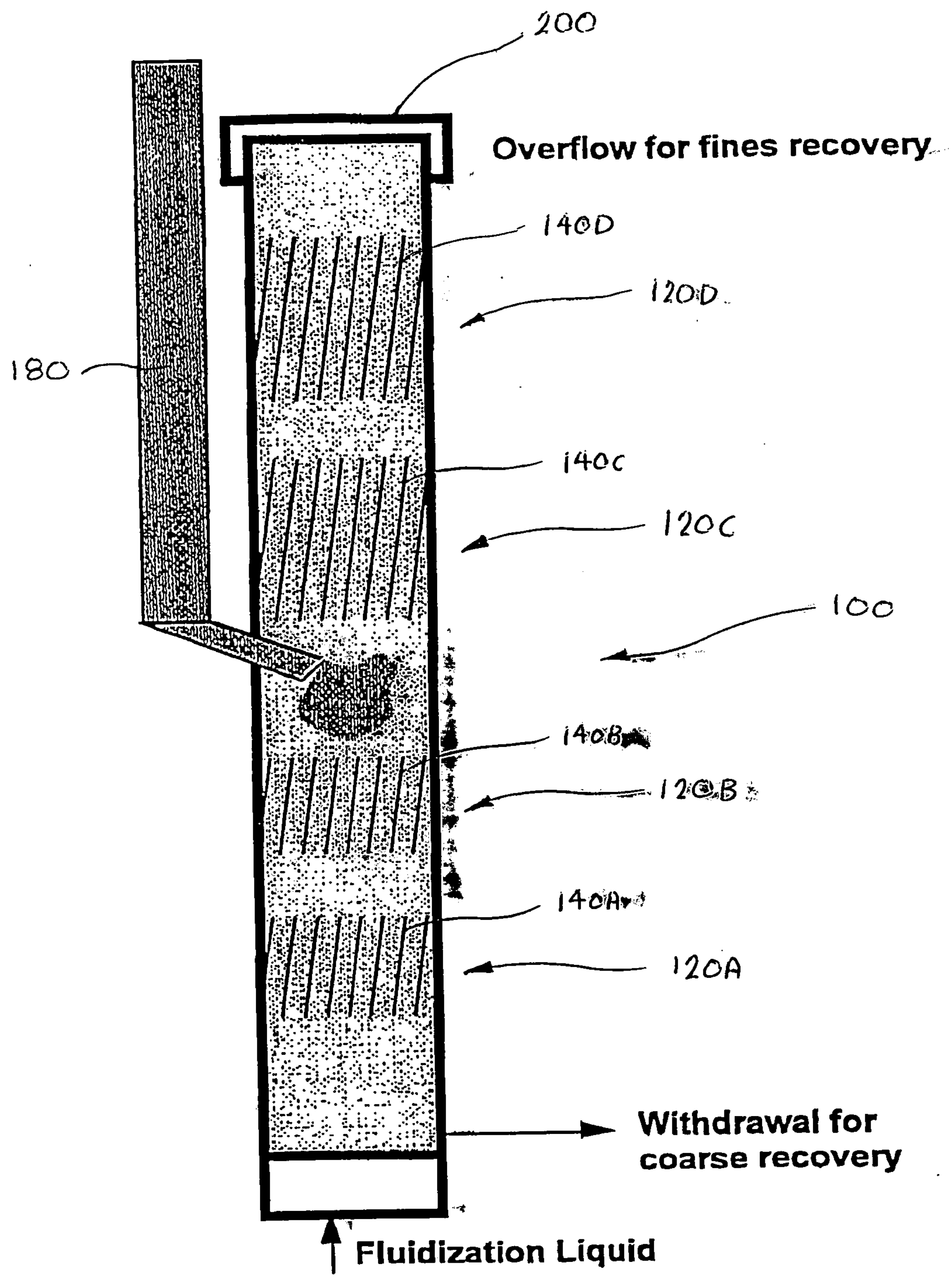
200
Overflow for fines recovery
140D
120D
180
140C
120C
100
140B
120B
140A
120A
Withdrawal for
coarse recovery
Fluidization Liquid

FIG. 3